Oil Shales: Their Shear Story

Jyoti Behura,

Mike Batzle, Ronny Hofmann

Geophysics Department

John Dorgan

Chemical Engineering Department

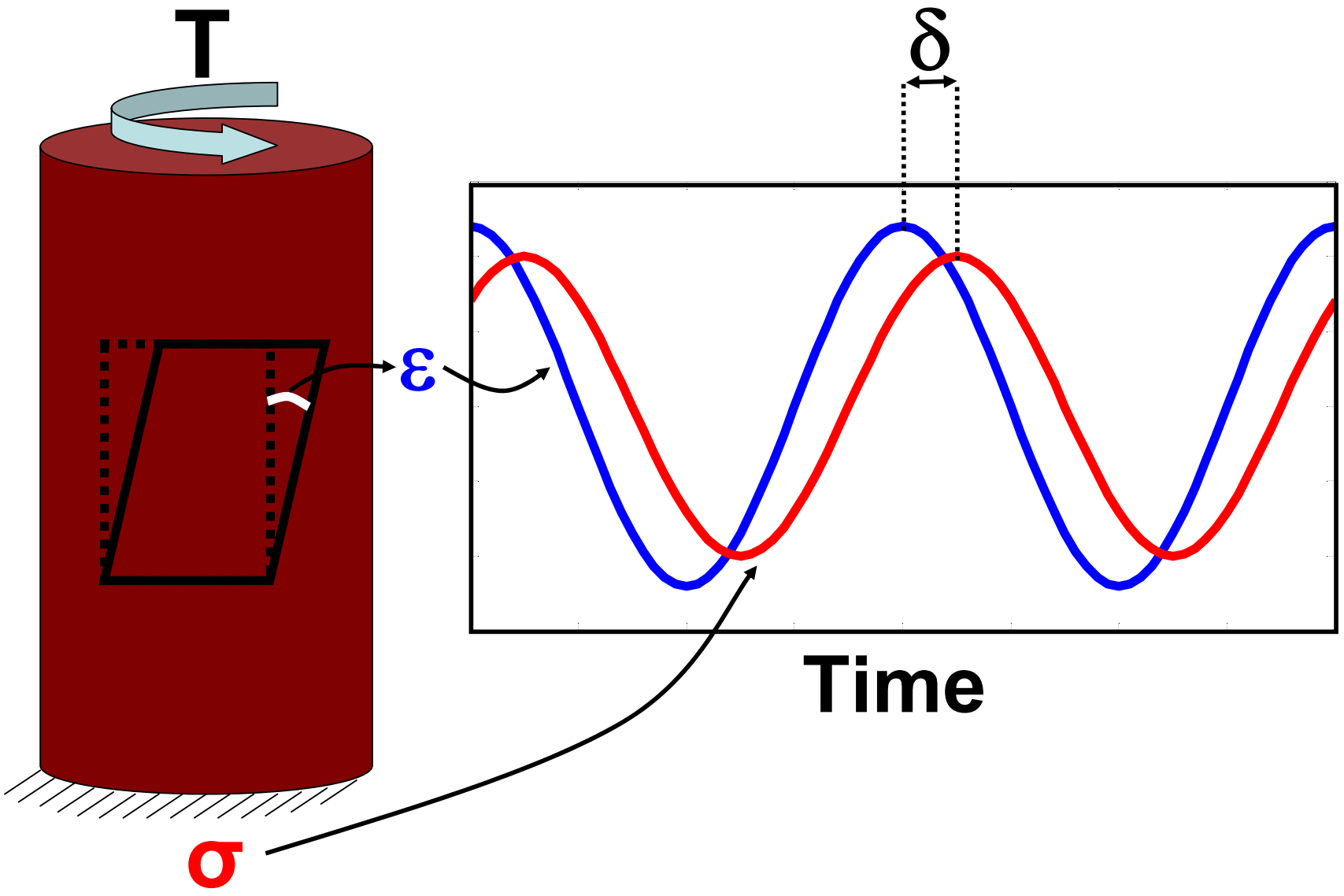
Colorado School of Mines

Facts

- Huge reserves
- Environmental issues
- In-situ recovery

Why shear properties?

Experiment



Dynamic Properties

$$\epsilon = \epsilon_0 e^{-i\omega t}$$

$$\sigma = \sigma_0 e^{-i(\omega t - \delta)}$$

Dynamic Properties

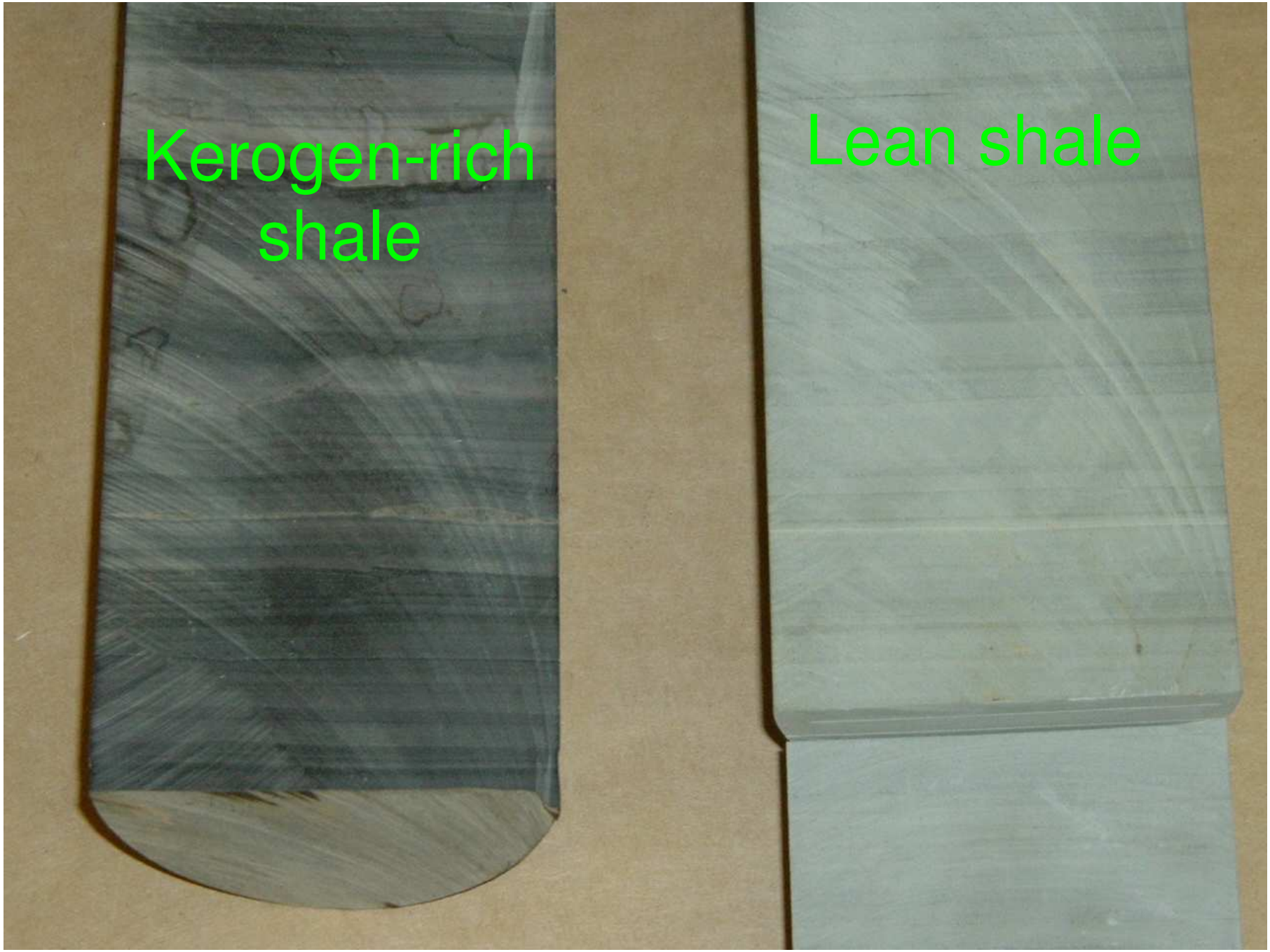
$$\epsilon = \epsilon_0 e^{-i\omega t}$$

$$\sigma = \sigma_0 e^{-i(\omega t - \delta)}$$

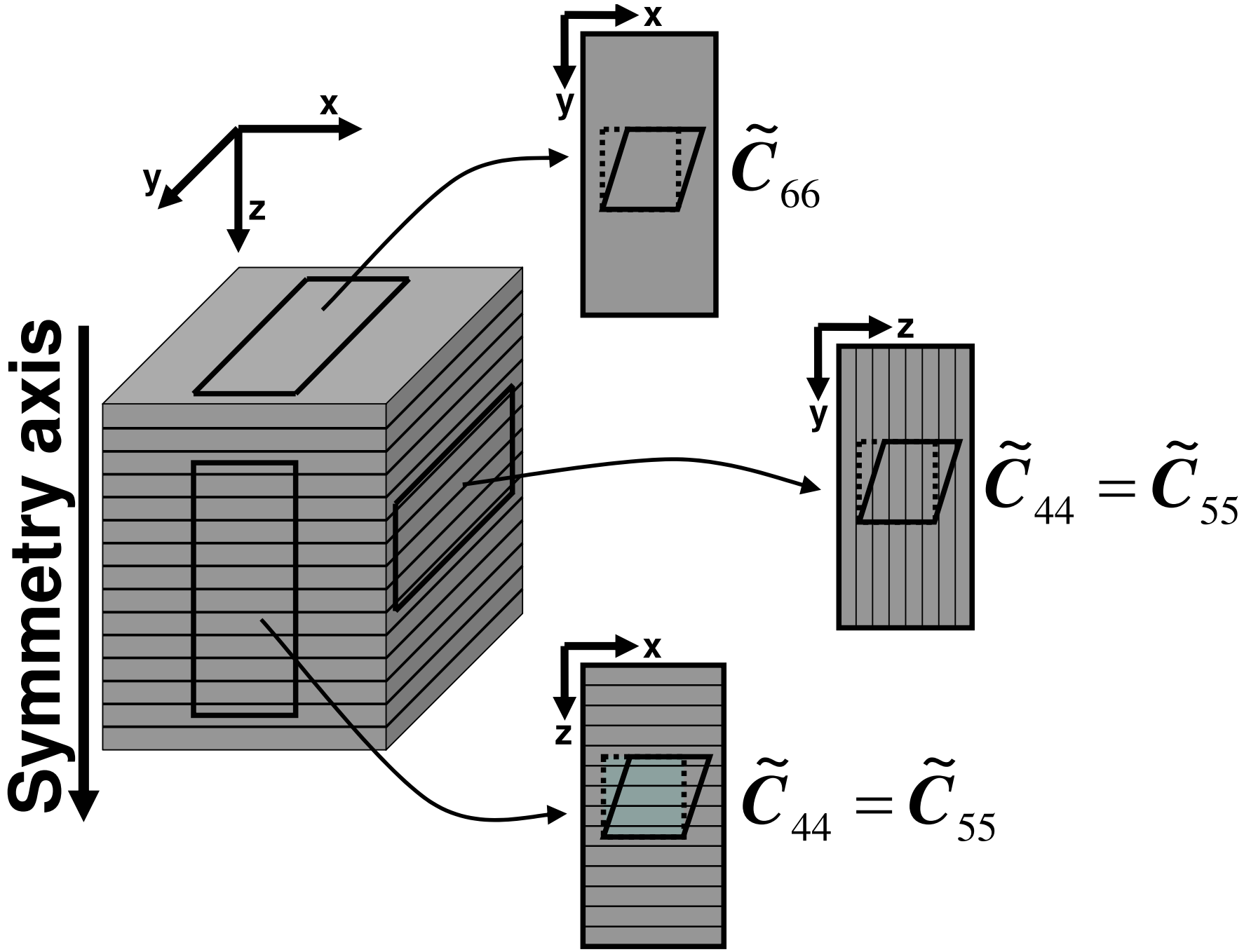
$$G = \frac{\sigma}{\epsilon} = G' + iG''$$

$$Q = \frac{1}{\tan\delta} = \frac{G'}{G''}$$

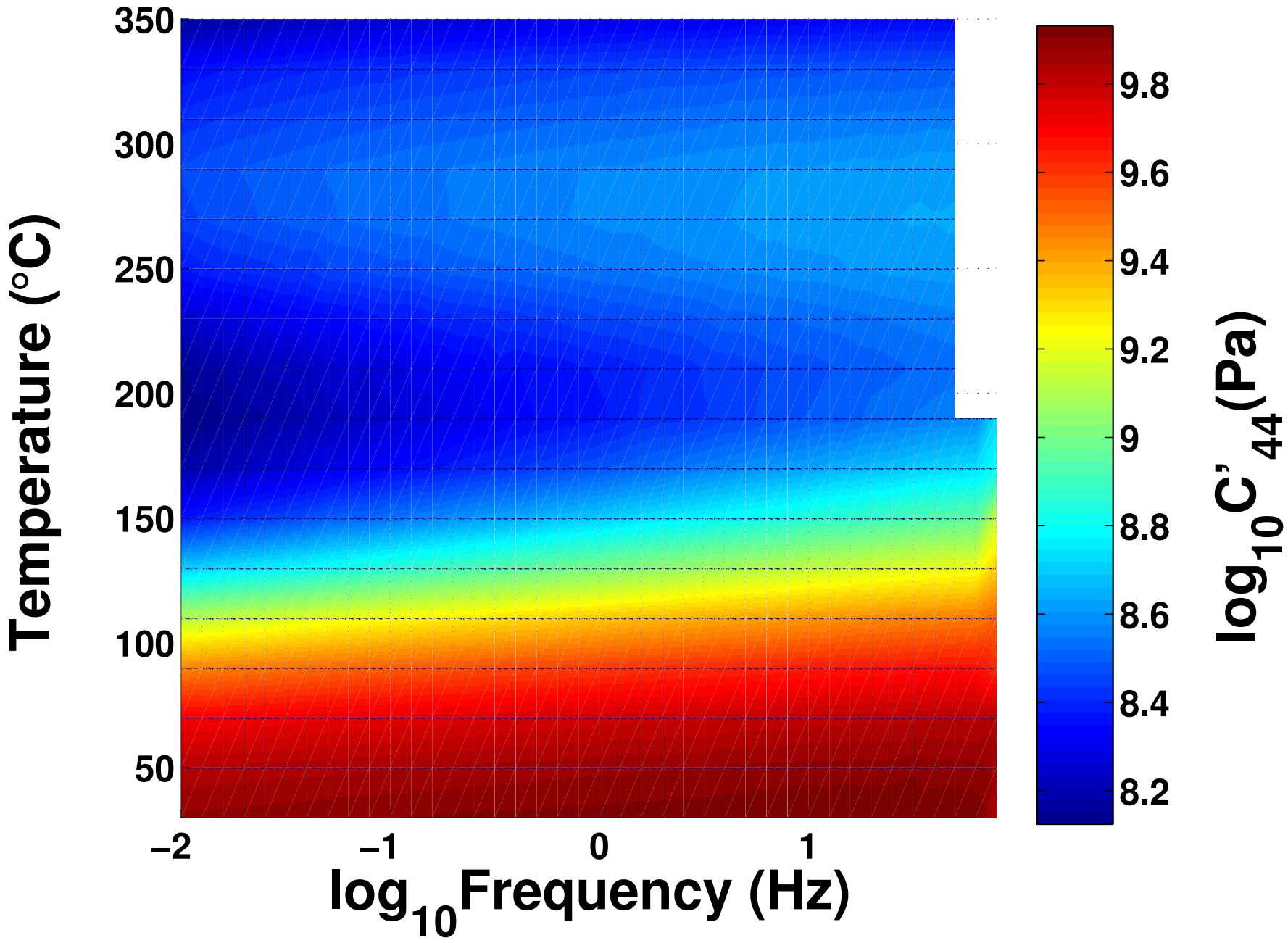
Oil Shale Samples



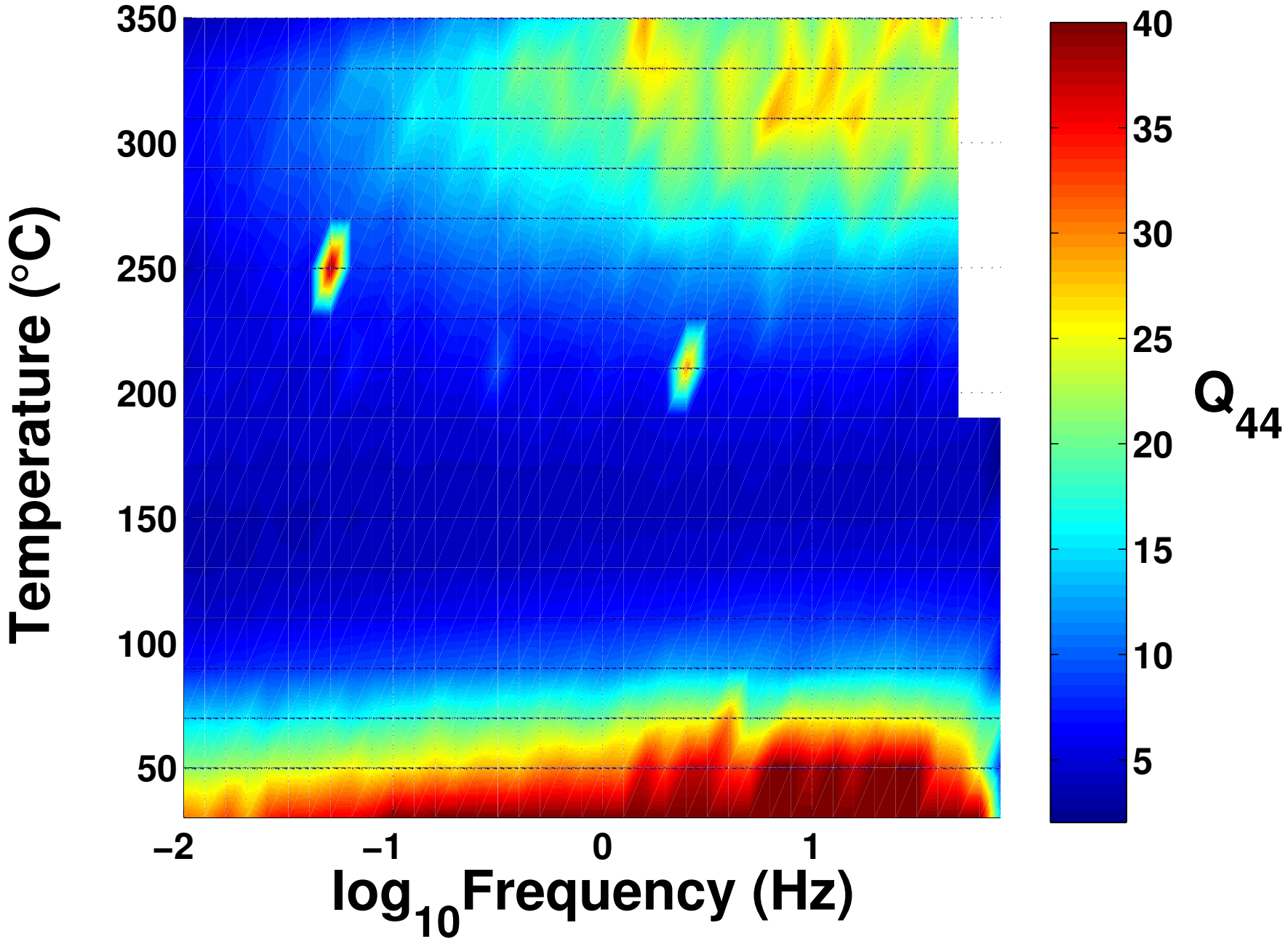
Different Samples



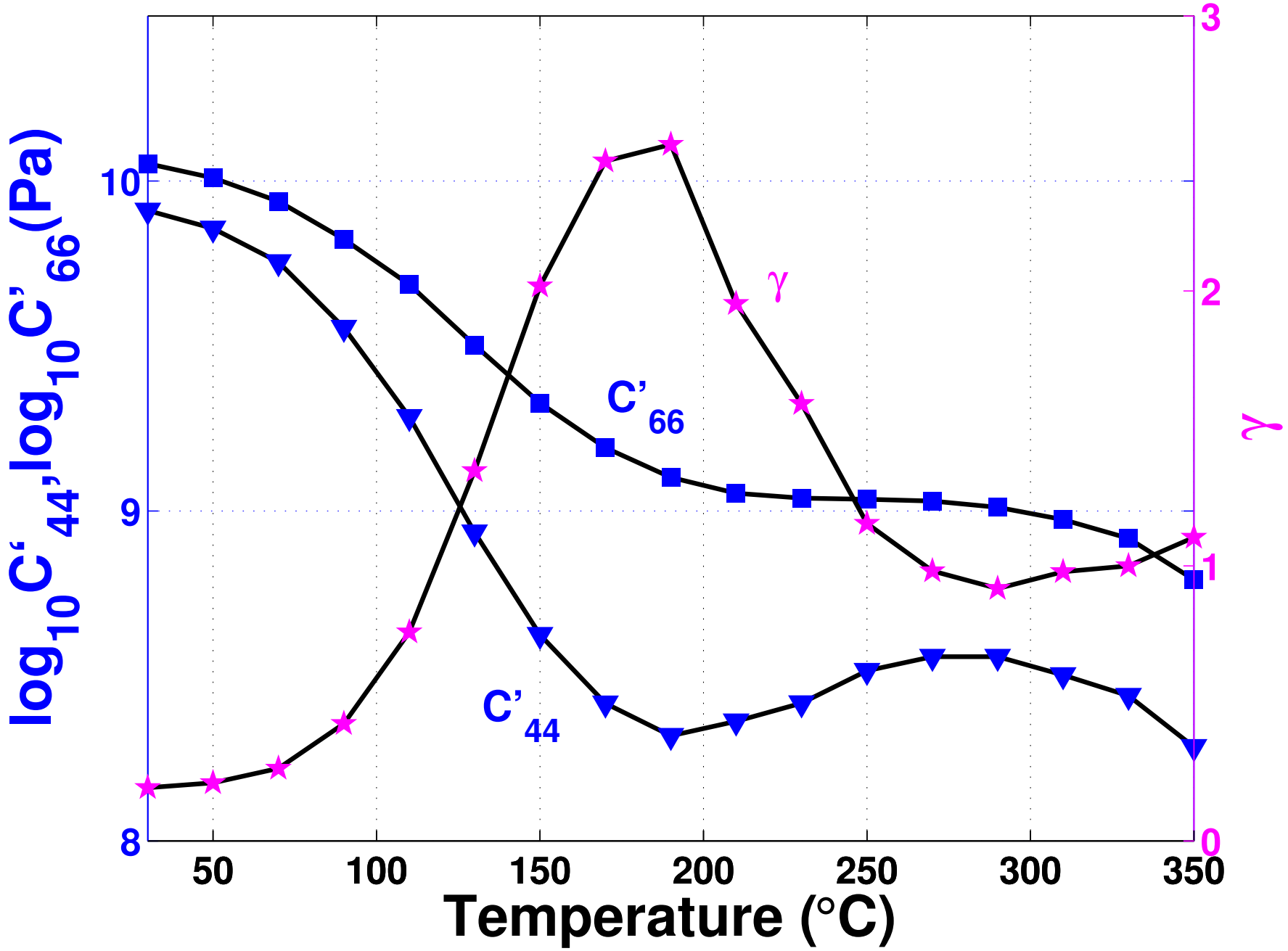
Kerogen-rich Shale C'_{44}



Kerogen-rich Shale Q_{44}

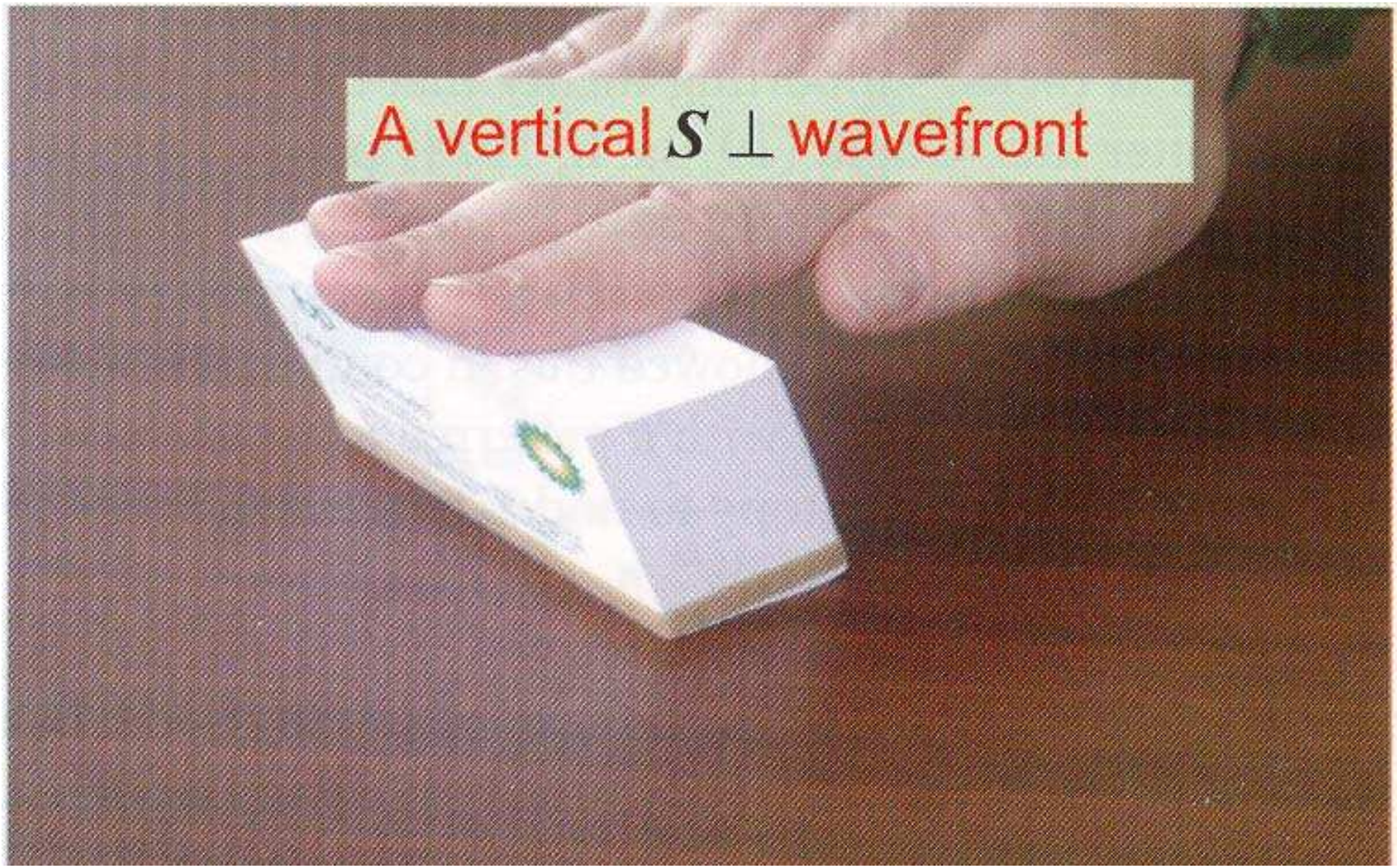


Velocity Anisotropy

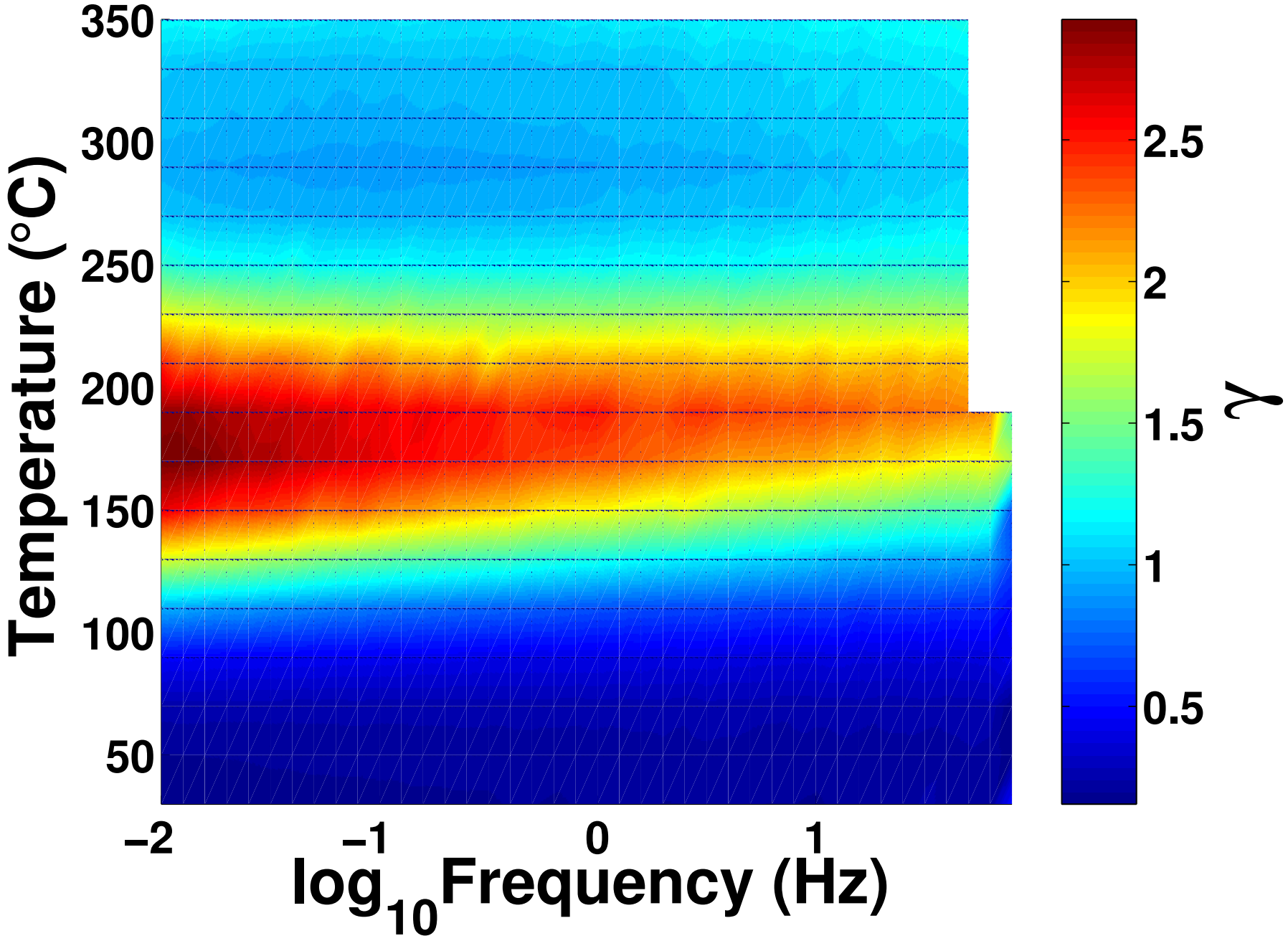


C_{66} Analogy

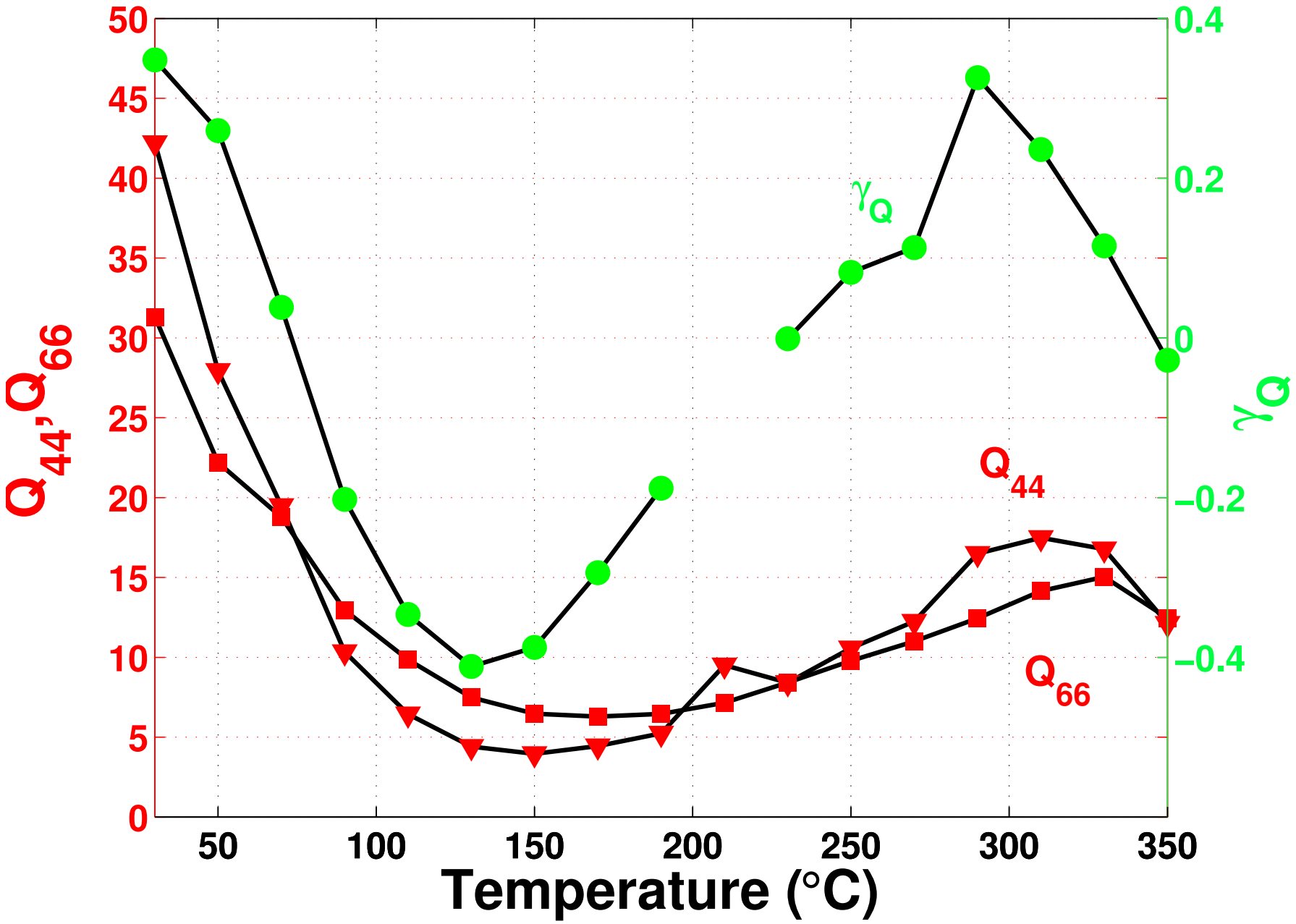
C_{44} Analogy



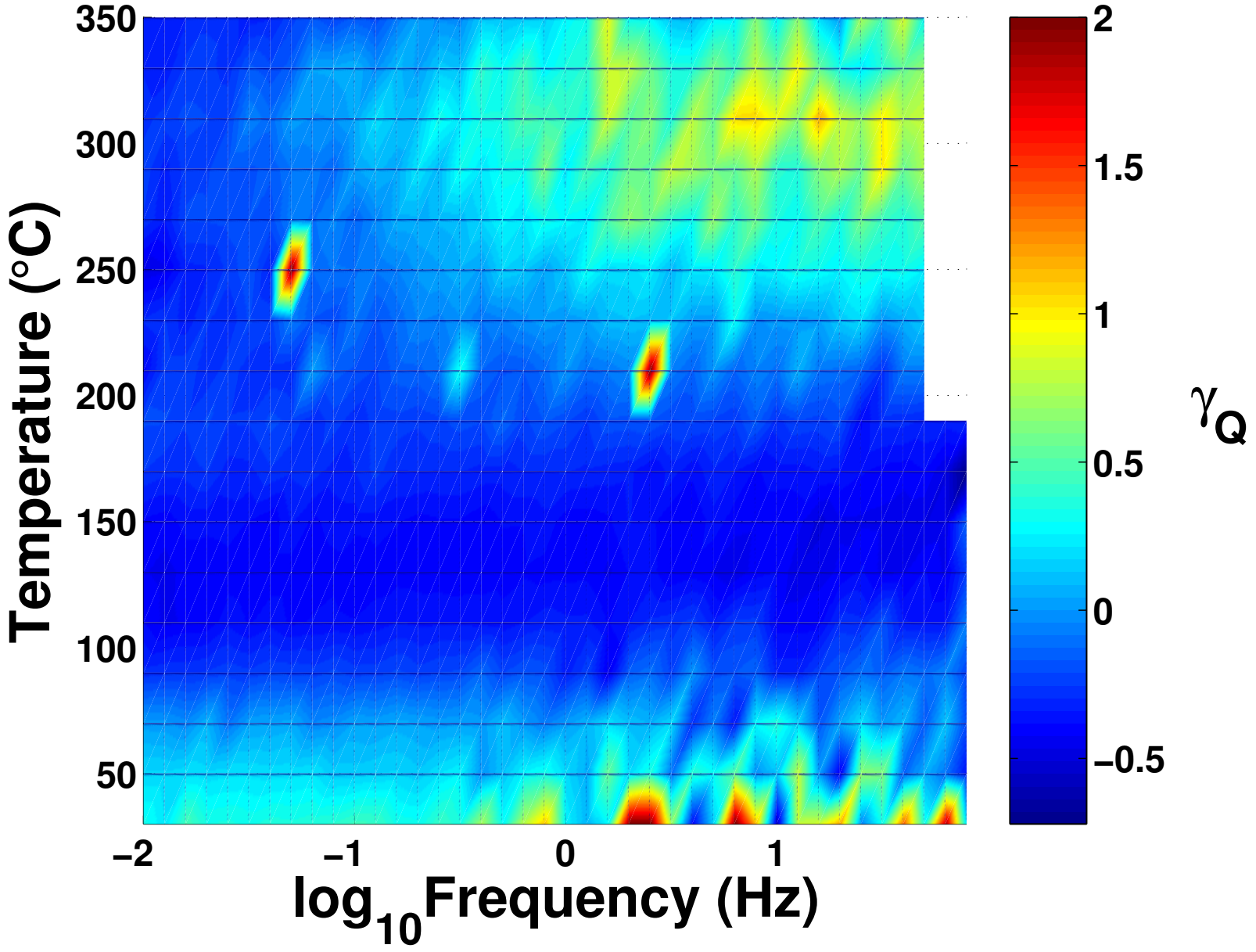
Thomsen Parameter γ



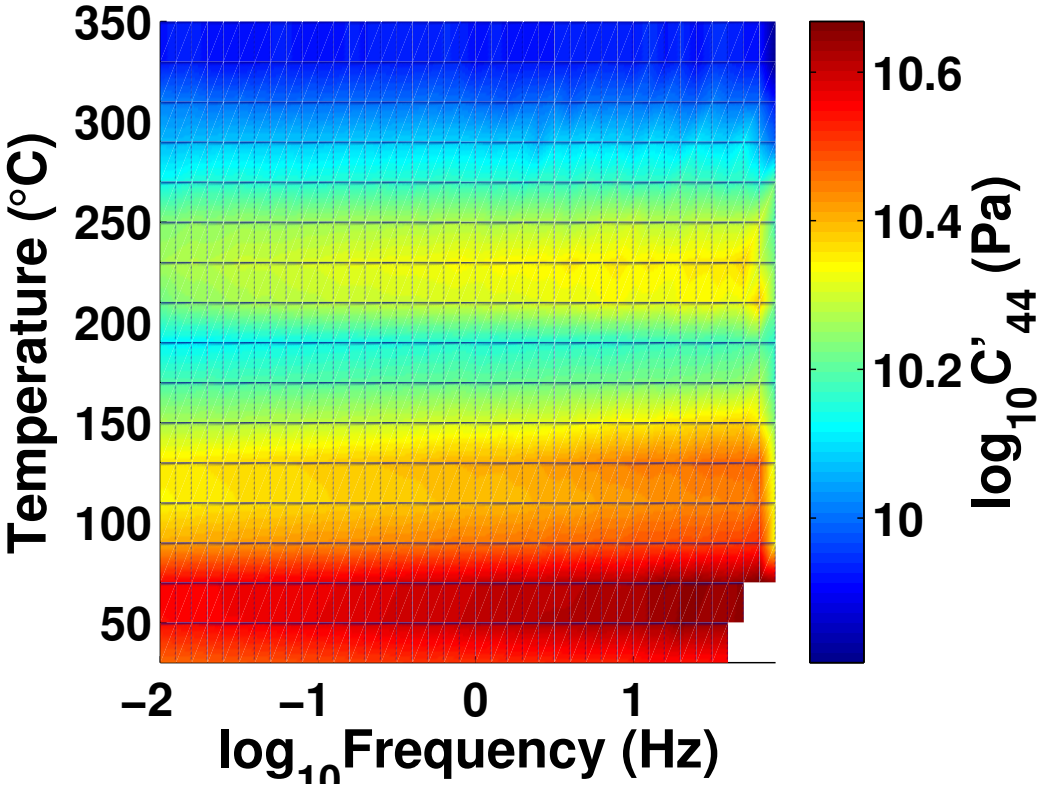
Attenuation Anisotropy

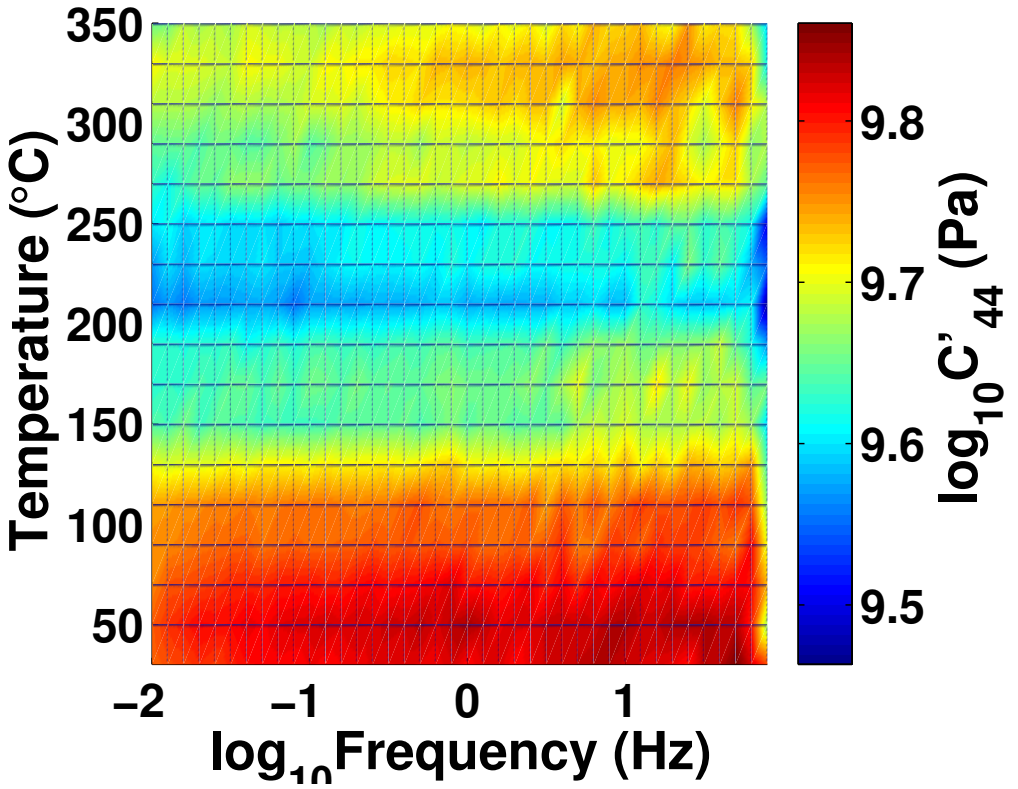


γ_Q


350
300
250
200
150
100
50
Temperature (°C)
−2
−1
0
1
log10Frequency (Hz)
2
1.5
1
0.5
0
−0.5
γQ

Confining vs. Constant Axial Stress

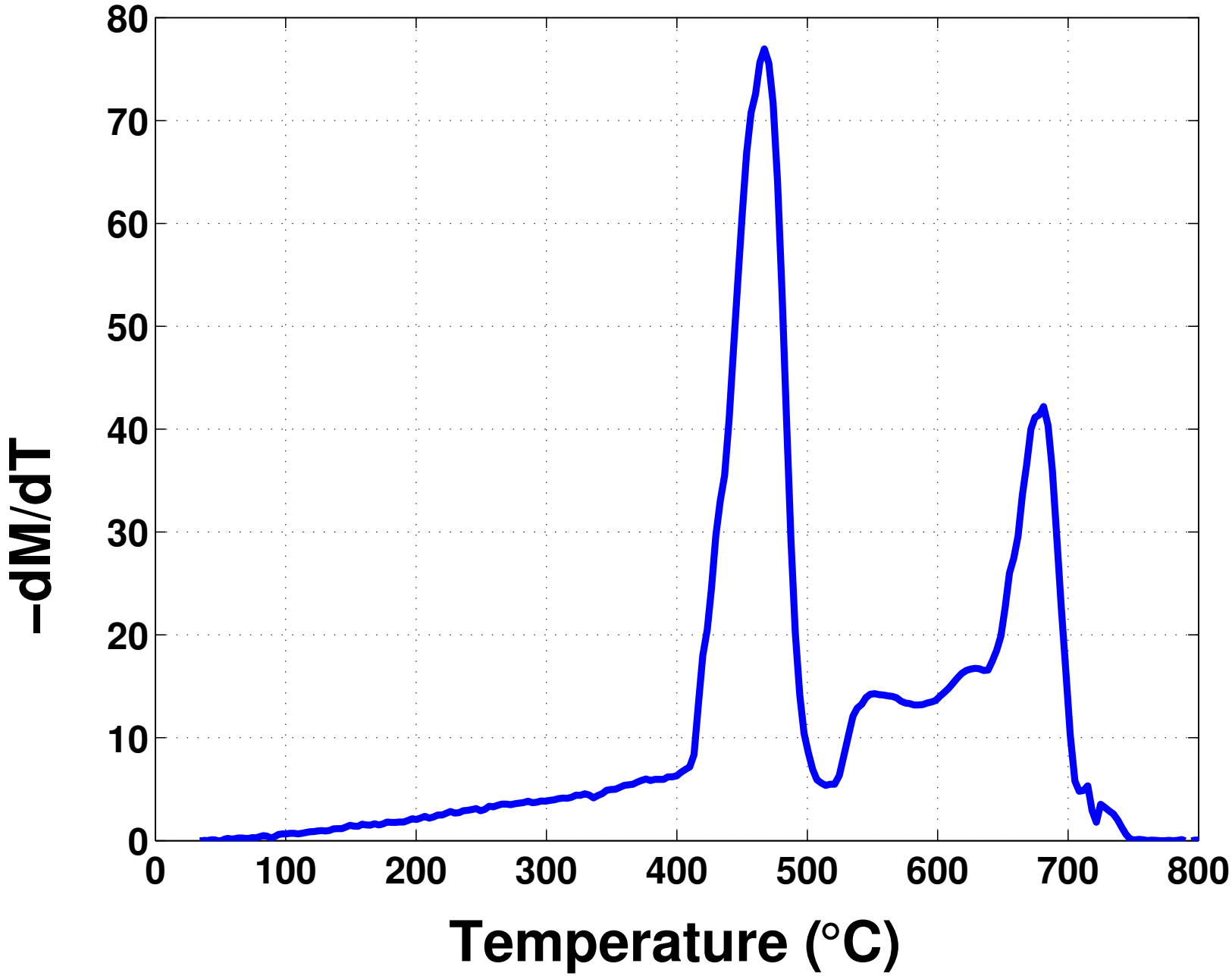




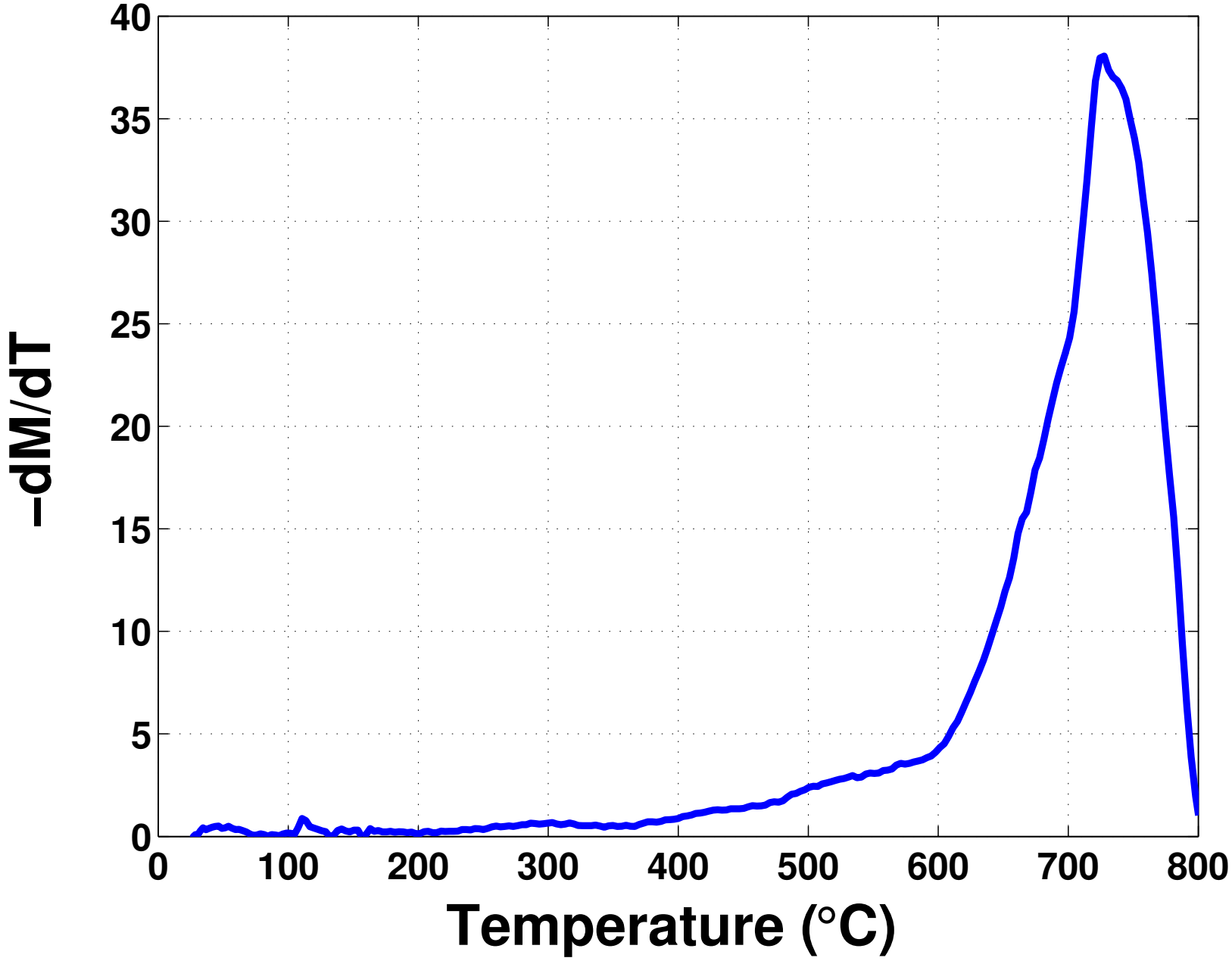
Conclusions

- Q, G: weak freq. dependence
- Q, G: strong temperature dependence
- Strong anisotropy
- $G'_{lean} > G'_{kerogen}$
  $Q_{lean} > Q_{kerogen}$

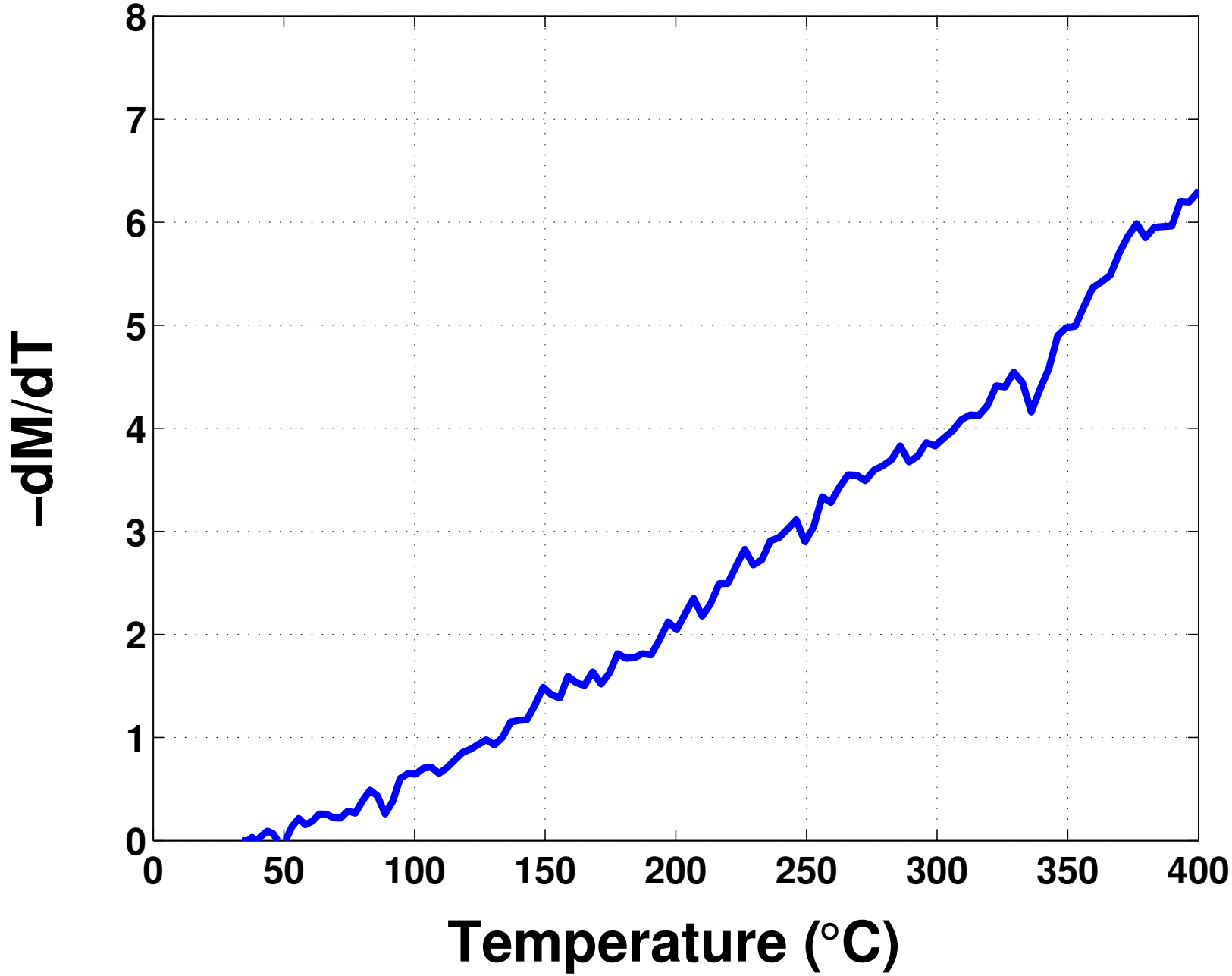
TGA: Kerogen-rich



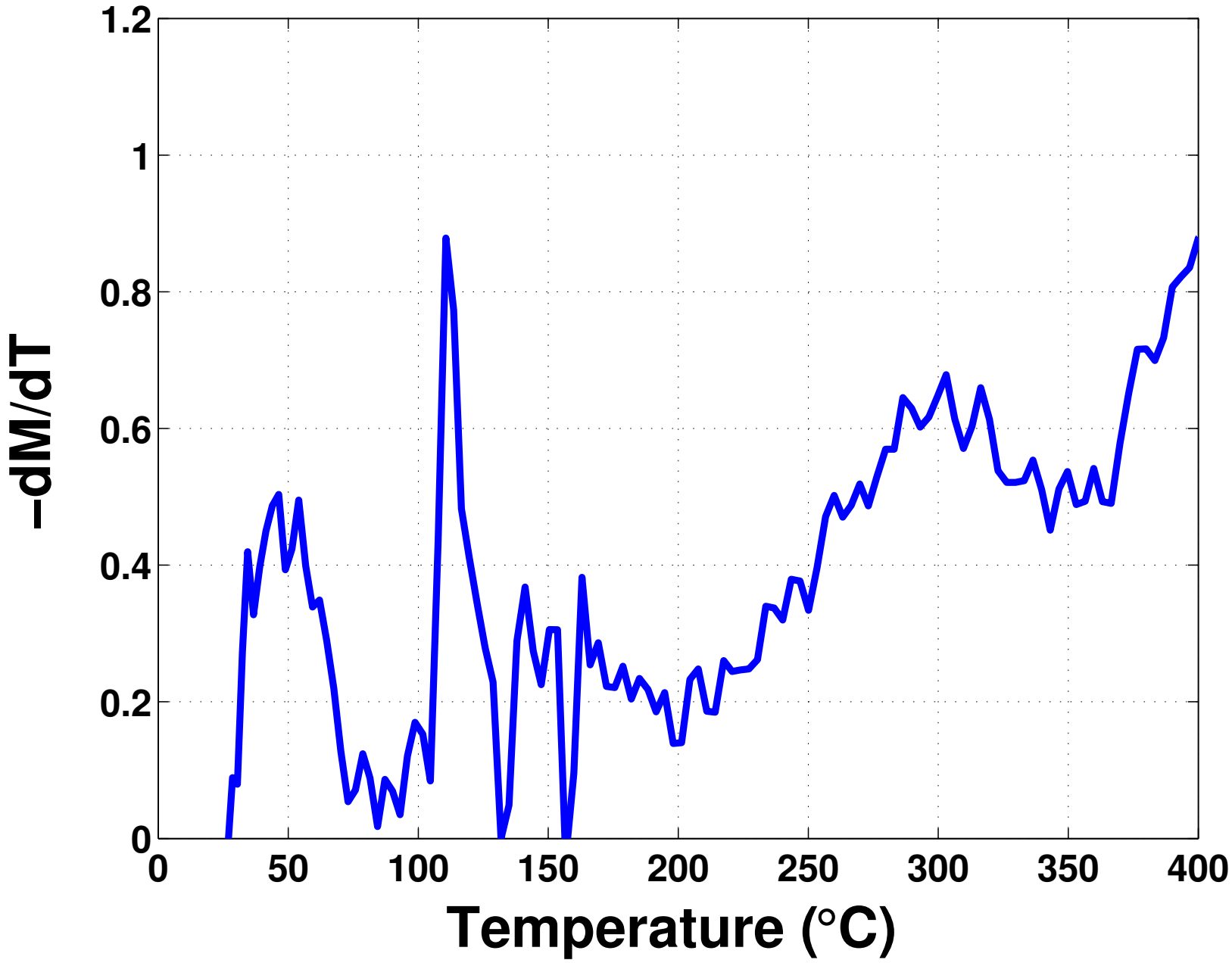
TGA: Lean


40
35
30
25
20
15
10
5
0
−dM/dT
0
100
200
300
400
500
600
700
800
Temperature (°C)

TGA: Kerogen-rich (zoom)



TGA: Lean


1.2
1
0.8
0.6
0.4
0.2
0
−dM/dT
0
50
100
150
200
250
300
350
400
Temperature (°C)